AIR QUALITY TRENDS IN THE SUDBURY AREA 1953 – 2002[1]

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Abstract: Monitoring programs undertaken by the Ontario Government since the mid-1950s have shown significant improvements in air quality in the Sudbury area. These improvements have led to a very successful environmental recovery, which together with a sustained re-greening program have earned community recognition. The results show that sulphur dioxide (SO_2) levels in the City of Greater Sudbury decreased by 50% immediately following the abatement measures undertaken in 1972. Equally significant improvements were realized in the ensuing decades, such that by the mid-1990s, the occurrence of SO_2 fumigations potentially injurious to vegetation had become isolated events. Since 1999, the frequency of exceedance of the 1-hour provincial criterion for SO_2 has fallen 85% from the early 1990s. Good to very good Air Quality Index (AQI) readings were reported more than 94% of the time. Moderate to poor AQI values were largely attributed to elevated ground-level ozone and to a much lesser extent to SO_2. In comparison to other selected cities in Ontario, the City of Greater Sudbury ranked as one of the best for a number of air pollutants during the period 1990 to 2002.

Key Words: air quality, sulphur dioxide, City of Greater Sudbury, Air Quality Index, air pollutants.

Introduction

Air quality in the City of Greater Sudbury, due to historical air emissions from one of the world's largest metal smelting complexes, is a well known topic that has brought much unwanted attention to the area. Pictures of industrial barrens, acid-damaged lakes and of the "Superstack", the world's tallest smokestack, have historically tainted the area with an undesirable image. However, from the evidence of environmental recovery following emission reductions from local smelters and much improved air quality, and from the 'United Nations' recognition of its very successful re-greening program, the City of Greater Sudbury has assumed a more favorable international reputation.

This paper provides a summary of the results of SO_2 air quality monitoring programs undertaken by the Ontario Government in the Sudbury area since the mid-1950s, and documents the significant improvements in local air quality realized in the past three decades. Although historical air quality is of significant interest and will be reviewed, the focus is on more recent trends and the current state of air quality in the City of Greater Sudbury based on measurements of SO_2. The results of this analysis are compared to those from other urban centers in Ontario, namely Toronto, Hamilton, Ottawa, Sault Ste Marie and Thunder Bay for the period 1990 to 2002. The paper briefly describes the evolution of the SO_2 monitoring network in the Sudbury area and provides an overview of the actions taken to reduce smelter emissions.

This paper was prepared from a report[3] commissioned by the Clean Air Sudbury Committee to provide a baseline of information to stakeholders and decision makers for discussions on possible future actions to further improve air quality in the City of Greater Sudbury.

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Background

Sulphur dioxide (SO_2) is a colorless gas caused by the combustion of sulphur-bearing substances. It can be transformed to sulphur trioxide (SO_3), which in the presence of water vapor readily becomes sulphuric acid (H_2SO_4) mist. Sulphur dioxide can also be oxidized to form acid aerosols. It is a precursor to sulphates, which are significant components of fine particulate matter in the atmosphere.

More than two thirds of the SO_2 annually emitted in Ontario come from smelters, utilities and petroleum refineries. Of these, smelter emissions typically comprise the largest fraction; in 2001, smelters accounted for 44% of provincial emissions (Environment Ontario, 2002). Other industrial sources include steel mills and pulp and paper mills. Lesser sources include residential, commercial and industrial space heating. In the City of Greater Sudbury, the principal sources of SO_2 emissions are the CVRD Inco (formerly INCO Ltd.) and Xstrata Nickel (formerly Falconbridge Ltd.) smelters. The Environment Canada Canadian Emissions Inventory of Criteria Air Contaminants for 2005 (Environment Canada, 2005) estimated smelter contributions to be 91.3% of the total. Emissions from other industrial and transportation sources in the Sudbury area accounted for 6.3% and 2.4% of the total, respectively.

In Ontario, the responsibility for air quality management rests with the Ministry of the Environment (MOE), created in 1970. The MOE has established two types of concentration limits for a large number of air pollutants for acceptable air quality: air quality standards and ambient air quality criteria (AAQC). The standards are listed in Regulation 346 and are known as Point of Impingement (POI) standards. They apply over half-hour averaging periods and are used by MOE approvals engineers in their review of applications for the issuance of certificates of approval for new or existing facilities that emit air pollutants.

On the other hand, the AAQCs are desirable concentrations for acceptable air quality. They are defined in Regulation 337 and cover averaging periods in some cases as short as 10 minutes, but more commonly for periods of 1 hour, 24 hours and 1 year. Unlike the POI standards, they are not legally enforceable unless they are specified in a control document such as a certificate of approval or a control order issued by the MOE. It is important to note that in 2005, the MOE replaced Regulations 346 and 337 with a new air regulation (O. Reg. 419/05). Under this new regulation, the 1-hour and 24-hour AAQCs for SO_2 are legally enforceable standards and the SO_2 annual AAQC has been removed. However, the AAQCs for SO_2 under Regulation 337 will be used in this paper and they are listed in Table 1, as well as their limiting effects.

Weather has a major influence on air quality. The dispersion and behavior of air contaminants is directly affected by wind, temperature, precipitation, sunshine and the stability condition of the atmosphere. The latter is driven by the temperature of the air as a function of altitude. This 'temperature profile' dictates whether the air is stable, i.e. very little vertical movement, or unstable, i.e. with significant vertical movement which is the case with updrafts and downdrafts. Air pollutants released in unstable air can reach ground-level due to downdrafts, even if released from elevated stacks. In the Sudbury area, SO_2 episodes or fumigations occur when SO_2 emitted even at significant heights from smelter stacks impinges at ground level. This 'looping plume' phenomenon typically occurs under sunny conditions from late spring to early fall - from late morning to mid-afternoon - when the air is most unstable and mixes down to the ground entraining parcels of sulphur dioxide gas released from the stacks and also to a much lesser degree from smelter building roof vents. This phenomenon is aggravated under light winds or stagnant conditions. Short term fumigations can also occur when the SO_2 plume is released below a temperature inversion, effectively preventing its upward dispersion. This can result in an accumulation of sulphur

[3] Air Quality Trends City of Greater Sudbury, Ontario 1953 – 2002, June 2004.

Table 1: Provincial ambient air quality criteria for SO_2.

Air Pollutant	Ambient Air Quality Criteria (AAQC)	Limiting Effect
Sulphur Dioxide	0.25 ppm (250 ppb) 1 hour	Vegetation protection
	0.10 ppm (100 ppb) 24 hours	Health protection
	0.02 ppm (20 ppb) 1 year	Vegetation protection

dioxide gas which is forced to mix down to the ground at elevated concentrations under the light wind conditions. From the fall through to the spring, i.e. when the atmospheric dispersion conditions are most favorable, the incidence of sulphur dioxide fumigations in the City of Greater Sudbury is typically very low and average sulphur dioxide concentrations are at background levels.

Smelter SO_2 Emissions and Control Programs

Since the turn of the century, more than 100 million tonnes of SO_2 have been released from the Sudbury basin due to the mining and smelting of sulphur bearing copper/nickel ores (Ontario/Canada Task Force, 1982). In the early 1960s, Sudbury's smelting complexes represented one of the largest point sources of SO_2 in the world (Summers, P.W., and D.M. Whelpdale, 1976). The history of sulphur dioxide abatement efforts and programs by the provincial government and industry is well documented (Ontario/Canada Task Force, 1982 and Gunn, 1995). Abatement efforts and strategies have focused on sulphur removal before smelting through rejection of the high sulphur iron minerals from the copper/nickel concentrates at the ore processing stage, the containment of sulphur through the production of sulphuric acid and liquid SO_2, and roasting/smelting process improvements to increase the efficiency of sulphur containment and production of these by-products.

Historical trends in emissions of SO_2, shown in Fig. 1, illustrate the magnitude of Sudbury area sources and the success of abatement efforts since the 1960s. In addition to legislated requirements for emission reductions imposed by the provincial government since the 1970s, labour disruptions and periods of reduced nickel production (1966, 1969, 1975, 1978, 1979, 1982, 1983, and 1994) contributed to the significant decline in SO_2 emissions. In comparing the first and last 5 years of the period 1960 to 2002 shown in Figure 1, annual average emissions have decreased by about 88%. In February 2002, the MOE issued an Order imposing lower SO_2 emission limits on Sudbury area smelters. Starting in 2007, the current collective annual limit of 365 kilotonnes (kt), in effect since 1994, will be reduced by 34% to 241 kt.

In spite of very substantial reductions in annual emissions, with their current smelting process and associated emission levels, the Copper Cliff and Falconbridge smelters cannot meet, at all times, the provincial 1-hour SO_2 ambient air quality criterion (0.25 ppm) and the half-hour standard (0.30 ppm) specified in Ontario Regulations 337 and 346 respectively. This is due to the 'looping plume' phenomenon which often results in short-term fumigations at ground-level. From the experience gained by the Tennessee Valley Authority in the U.S. during the late1960s/early 1970s, and by CVRD INCO after the commissioning of its tall stack in Copper Cliff in 1972, a supplementary emissions control strategy was found to be effective in reducing the intensity and duration of fumigations. The strategy consists of the timely reduction of SO_2 stack emissions through production curtailments during periods of poor atmospheric dispersion conditions. Weather forecasting and dispersion modelling are critical components of this strategy in order to determine when and how much to reduce production.

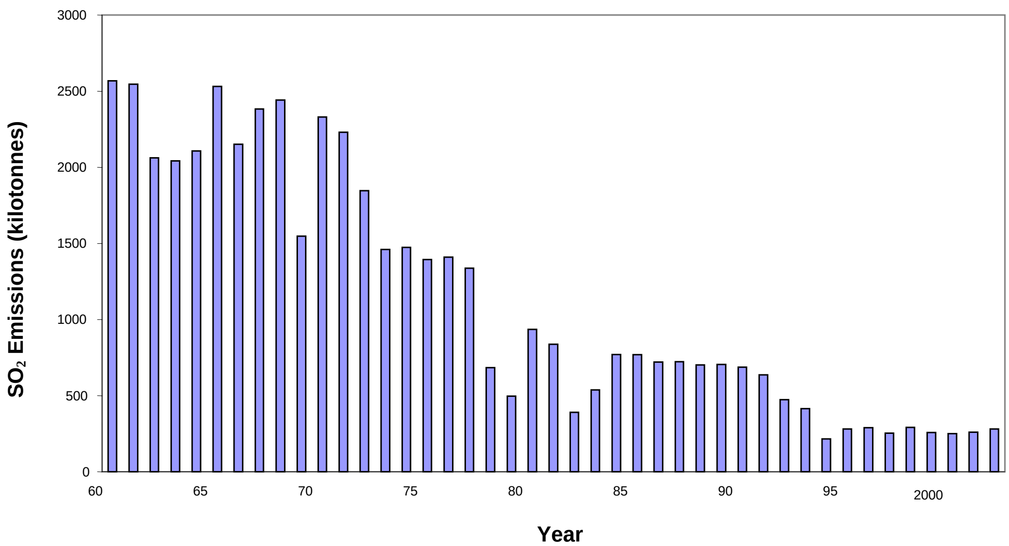

Figure 1: SO_2 emissions from Sudbury area smelters (1960-2002)

On the basis of knowledge and experience gained in the Sudbury area during the 1950s and 1960s on acute SO_2 injury to vegetation, a ground-level concentration of 0.50 ppm (500 ppb) for any 60-minute period was chosen as the short-term control limit for stack emissions. This strategy became a Ministry Control Order requirement for CVRD INCO in 1978 and for Xstrata Nickel in 1984.   In February 2002, the Ministry issued a revised Order imposing a lower supplementary emissions control limit of 0.34 ppm (340 ppb) on both smelters, effective April 2002. This lower control limit is the hourly Environment Canada maximum acceptable level for SO_2 in ambient air. The Order also requires both companies to complete a study by the year 2010 which identifies: the best available technologies and design, and their associated costs to meet the provincial sulphur dioxide half-hour standard of 0.30 ppm (300 ppb) and an implementation plan on how the standard would be achieved by the year 2015.

SO_2 Ambient Monitoring Program

In the past five decades, the SO_2 monitoring program has seen significant changes which are detailed in published Ministry of the Environment reports (Potvin and Balsillie, 1976 and 1978, Dobrin and Potvin, 1992). The original SO_2 monitoring network of stations operated by the province in the Sudbury basin was established in 1953 at the following locations as shown in Figure 2: Burwash, Skead, Grassy Lake, Garson and Lake Penage.   With the exception of Burwash, most of the stations were aligned along a southwest-northeast axis (Lake Penage to Grassy Lake) covering a distance of over 130 kilometres. At that time, ground-level concentrations of SO_2 were determined with Thomas autometers. These devices used a dilute sulphuric acid solution as the detection medium; the absorption of SO_2 in this solution changed its electrical conductivity which was then converted to a concentration of SO_2 in the air. Since, at that time, the damaging impact of SO_2 emissions on vegetation, such as forests, agricultural crops and gardens was the main concern, the stations were only operated during the growing season, i.e., from May to October. This measurement method was very labour intensive and the final results were only available the following fall or winter.

By 1970, another six stations (St Charles, Morgan, Rayside, Callum, Happy Valley near Falconbridge, and Ash Street in the city of Sudbury) had been added to the network. During the 1970s, significant changes to the network occurred with the introduction of better monitoring and data transmission technology; growing concerns within and outside the Sudbury basin about air quality impacts of emissions at greater distances from the tall stack commissioned in 1972 at the CVRD INCO Copper Cliff smelter; and the emergence of new issues such as acid deposition and possible health effects of sulphur dioxide. The network had grown to 17 stations by 1980 with sites as far away to the east and northeast as Verner and Lake Temagami. Most of the sites were converted to year-round operation in temperature-controlled shelters. By 1974 the Thomas autometers had been replaced by more automated wet-chemical SO_2 analyzers (the Davis and the Beckman 906A analyzers). By the mid to late 1970s, solid-state monitors, using the pulsed fluorescence detection principle began to replace these wet-chemical analyzers. Lastly, in 1978 the network was upgraded with the installation of a data telemetry system. It improved the accuracy and quality of the data and provided the Ministry, using telephone lines, with real-time 5-minute average readings from the SO_2 monitoring stations. Readings above a preset value triggered a telephone message to MOE staff for their notification and follow-up action with the responsible source as required. The data acquisition system stored the hourly average readings for transmittal to the Ministry's provincial database in Toronto.

The 1980s and 1990s brought an additional number of significant changes to the network. In 1985, the data telemetry system was enhanced with greater data storage and communications capabilities. The CVRD INCO and Xstrata Nickel facilities were provided access to the real-time 5-minute average readings for inclusion in their supplementary SO_2 control systems. It was then possible to transmit the hourly data electronically to the Ministry's Toronto computer for inclusion in the provincial Air Quality Information System (AQUIS) and for generating the hourly AQI values. Further enhancements to this system were made in the late 1990s with the substitution of data loggers with PCs and the use of a Windows-based operating system.

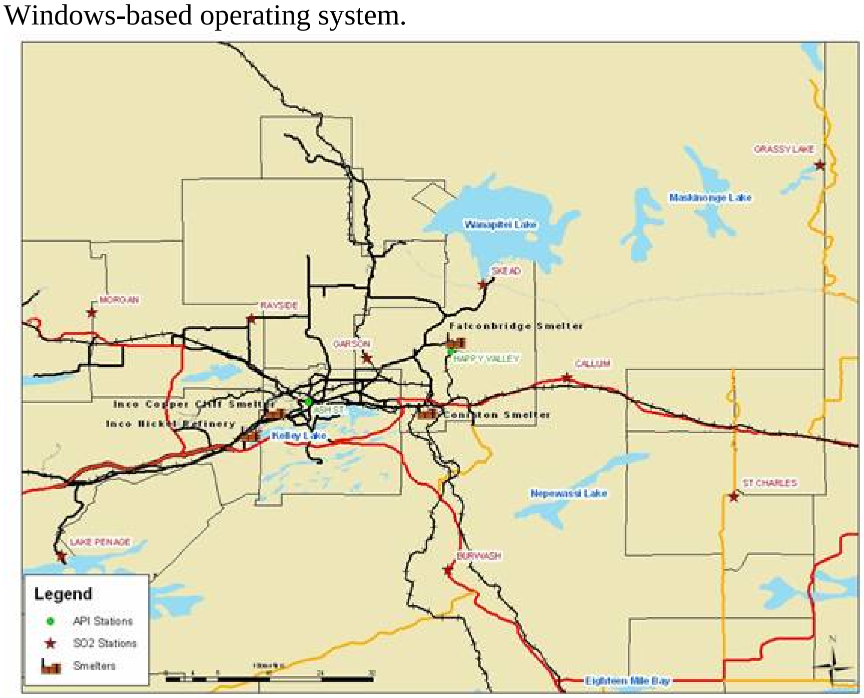

Figure 2: SO_2 monitoring network in the Sudbury Area (1953-1970)

The size and configuration of the network changed as well. Because of significant improvements in air quality outside the Sudbury basin due to decreasing emissions and greater dispersion afar from the tall stack at the Copper Cliff smelter, the more distant stations were decommissioned. In addition, decreasing SO_2 emissions from the tall stack at the Copper Cliff smelter resulted in lower stack gas volume and temperature with an accompanying negative impact on ground-level concentrations closer to the smelter due to reduced plume buoyancy/dispersion. Consequently, some of the more distant stations were relocated closer to the smelters and in populated areas within the City of Greater Sudbury. By the late 1990s, the network had been streamlined to 12 stations (see Figure 3), which is the size of the 2002 network.

SO_2 Monitoring Results

The 1950s and 1960s

In the 1950s and 1960s, ground level concentrations of SO_2 were oftentimes elevated at all monitoring locations in the Sudbury basin, with many exceedances of the Ministry's ambient air quality criteria. During the growing seasons from 1953 to 1964 (Dreisinger and McGovern, 1966), an elliptical area of about 540 miles^2 (over 1300 km^2) was exposed to average SO_2 concentrations in excess of the annual criterion of 0.02 ppm (20 ppb). In that area, maximum seasonal 1-hour readings would range from about 1 ppm (1000 ppb) to over 3.5 ppm (3500 ppb), well above the Ministry criterion of 0.25 ppm (250 ppb). In addition, this criterion would be exceeded during 100 to over 300 hours per season, whereas the 24-hour criterion of 0.10 ppm (100 ppb) would be exceeded for approximately 13 to 40 days per season.

During that period, many cases of vegetation injury associated with severe fumigations, sometimes as far as 80 km from the Sudbury smelters, were documented (McCallum 1964, Dreisinger, 1971). Extensive damage to area forests, and to a lesser degree to agricultural crops, was evident (Dreisinger and McGovern, 1964; Linzon, 1971). The size of area where sensitive species such as white pine were affected with severe-to-moderate injury covered more than 1800 km^2, with an additional 4000 km^2 of sporadic injury (Linzon, 1978).

Pre- and Post-1972

The combination of increased dispersal of pollutants, realized with the commissioning of the world's tallest (381 metres) smokestack at the INCO Ltd. Copper Cliff smelter in 1972, reduced emissions and the closure of obsolete plants led to dramatic improvements in local air quality after the early 1970s. A comparison of SO_2 ground-level concentration data collected from monitoring stations in operation during the growing seasons from 1967 to 1977, with 1972 as a transition year, demonstrates the extent of these improvements (Potvin and Balsillie, 1978) as shown in Figure 4. From over 181,000 hours of data collected in the period 1967 to 1971, 2423 hours exceeded the 1-hour criterion; the 24-hour criterion was exceeded on 189 days. For that period, the overall average concentration was 13 ppb. The seasonal mean in 1972 was 8 ppb. During the 'post-1972' period (1973-1977) and from over 187,000 hours of recorded data, 750 hours exceeded the 1-hour criterion and the 24-hour criterion was exceeded on 32 days. The overall average concentration for that period was 7 ppb. This analysis demonstrates that the measures undertaken in 1972 dramatically improved air quality in the Sudbury basin. The average concentration of SO_2 dropped very quickly by about 50% in the 'post-1972' period. Moreover, the frequency of excessive hourly values decreased by about 66%, and the frequency of 24-hour averages above the criterion fell by approximately 80%.

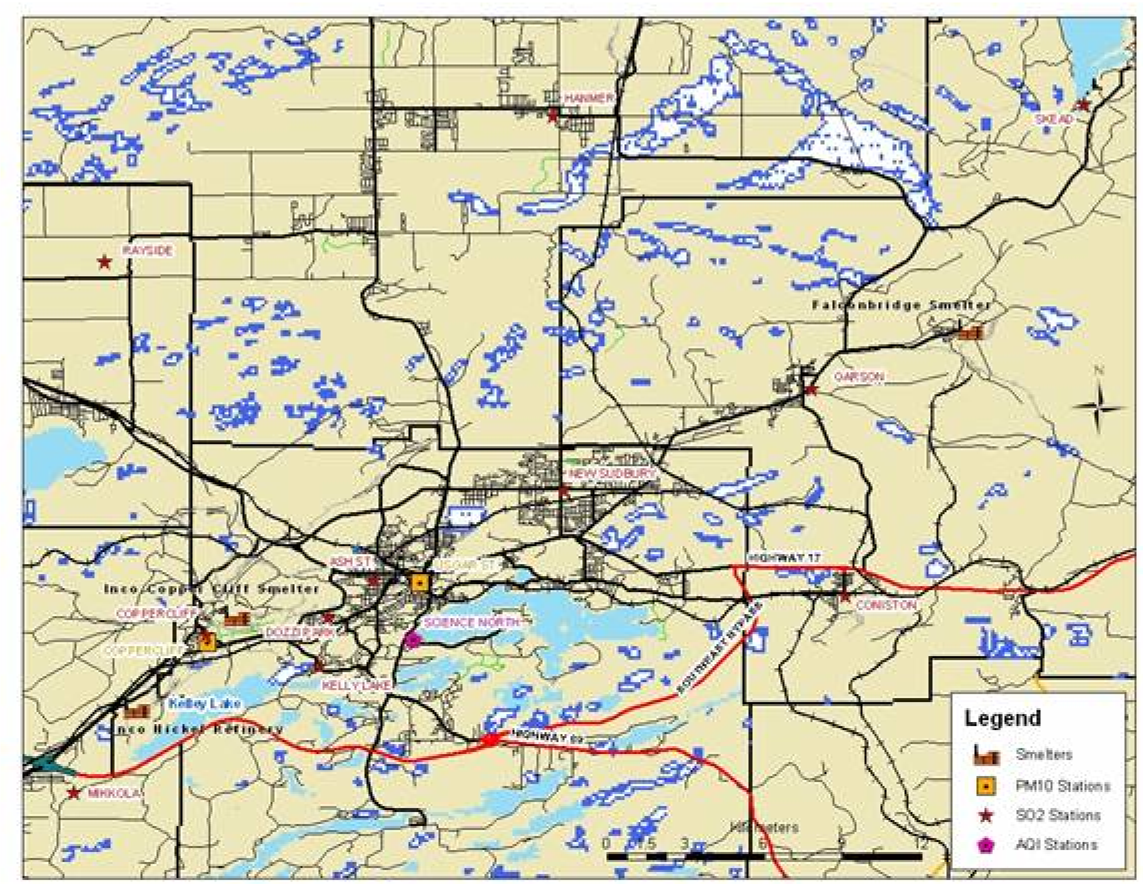

Figure 3: SO_2 monitoring network in the Sudbury area (2002)

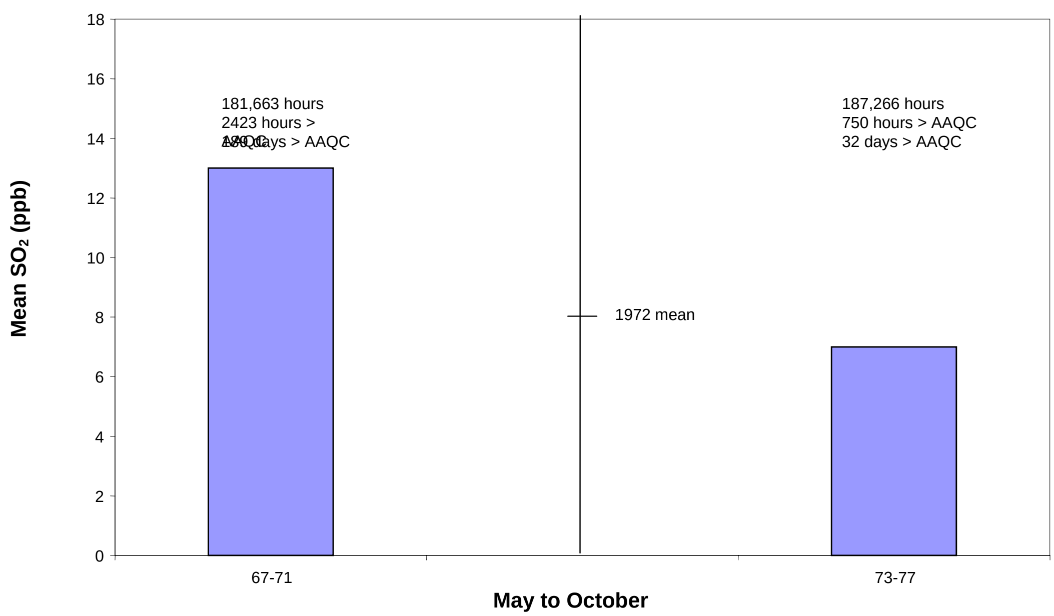

Figure 4: Mean SO_2 concentrations in the Sudbury area (1967-1971 and 1973-1977).

Long Term Trends

From the 2002 SO_2 monitoring network, the Skead, Garson (old and new) and Ash Street stations have the longest monitoring records, dating back to 1953 (Skead and Garson) and 1970 (Ash Street).

Historically, the Skead and Garson sites have been exposed to the highest measured concentrations of SO_2 in the Sudbury area. Since annual average concentration data only became available in the mid-1970s at these sites when they were converted to year-round operation, the best available trend indicator is the frequency of exceedance of the SO_2 1-hour and 24-hour criteria. The trend in the frequency of exceedance of these criteria for both sites combined, averaged per year for each decade, is illustrated in Figure 5. The significant improvements realized in the 'post-1972' era have been surpassed over the past 23 years; the exceedance frequency of the 1-hour and 24-hour criteria in the 1990s was 90% and 97% lower, respectively, than in the 1970s.

Annual average concentrations of SO_2 have also steadily decreased since the 'post 1972' era. A typical trend is shown in Figure 6 at the Ash Street site in Sudbury. The annual criterion was last exceeded at that location in 1975. Since then, the annual means have trended downwards and in the past decade, they have leveled off at about 6 ppb, roughly one half of the average values measured in the late 1970s.

Recent Trends (1990 – 2002)

The trend in the composite annual mean SO_2 concentrations for the 2002 monitoring network is shown in Figure 7 for the period 1990 to 2002. Since 1992, the composite mean has been rather constant, ranging from 3.7 ppb to 5.5 ppb. During that time, all sites recorded annual mean concentrations lower than the annual criterion of 20 ppb. The Copper Cliff station, shown separately in Figure 7, recorded the highest 13-year composite mean. It also realized the most significant improvements with the annual mean SO_2 concentrations falling from 20 ppb in 1990 to 5 ppb in 2002.

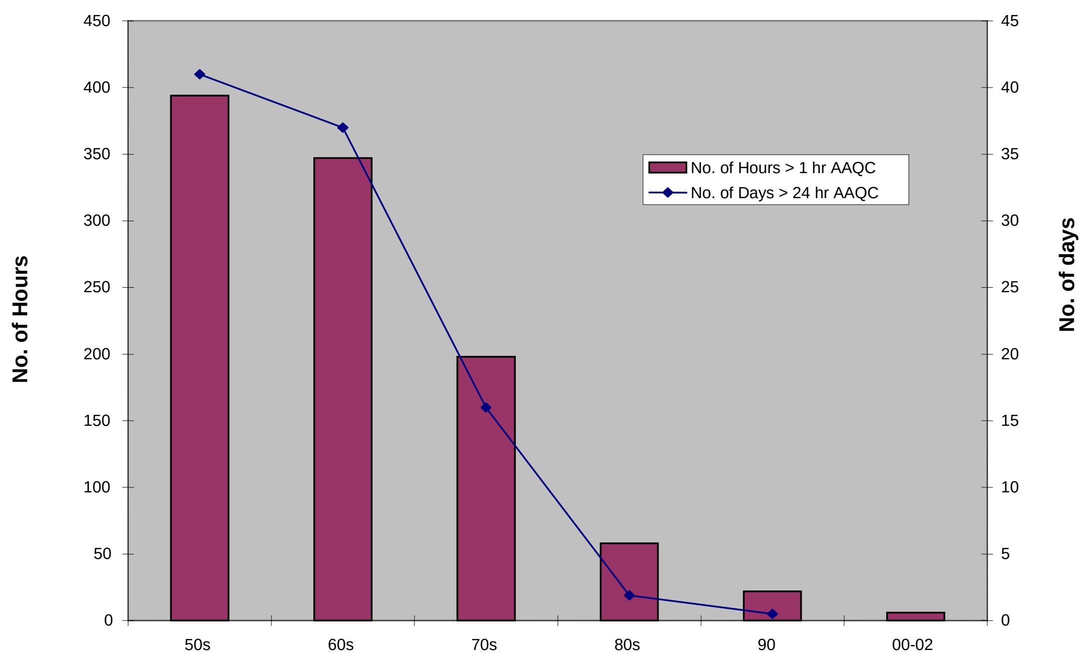

Figure 5: Exceedance frequency of the SO_2 AAQCs at Skead and Garson

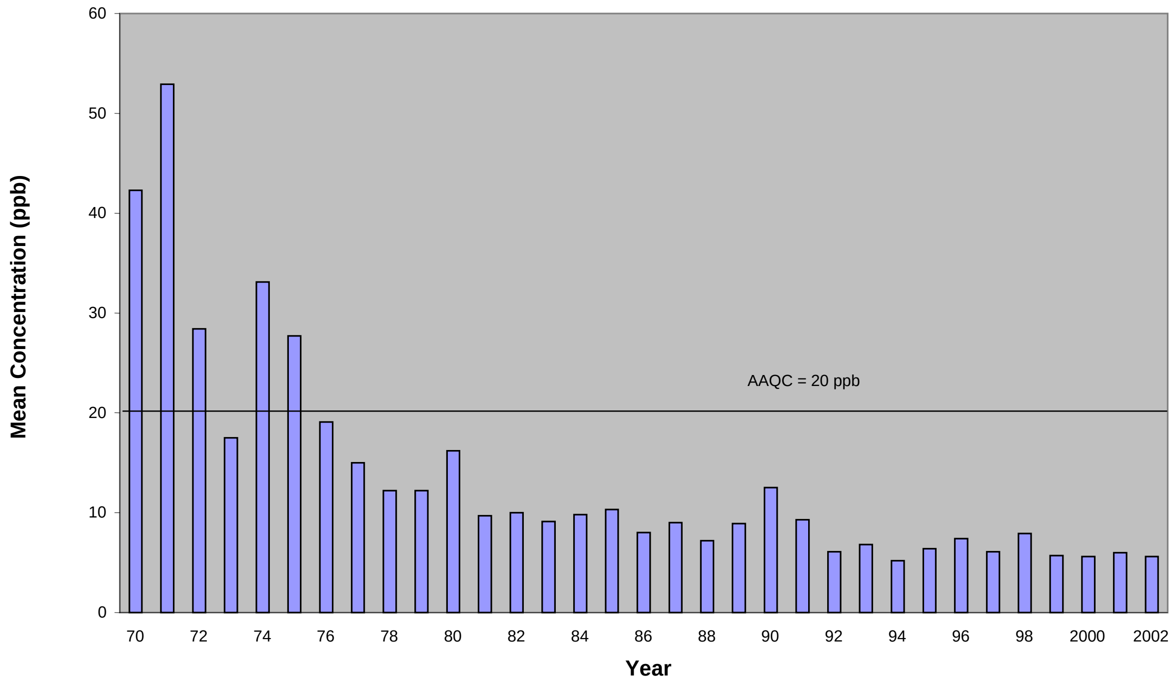

Figure 6: Mean SO_2 Concentrations at Ash Street in Sudbury (1970-2002)

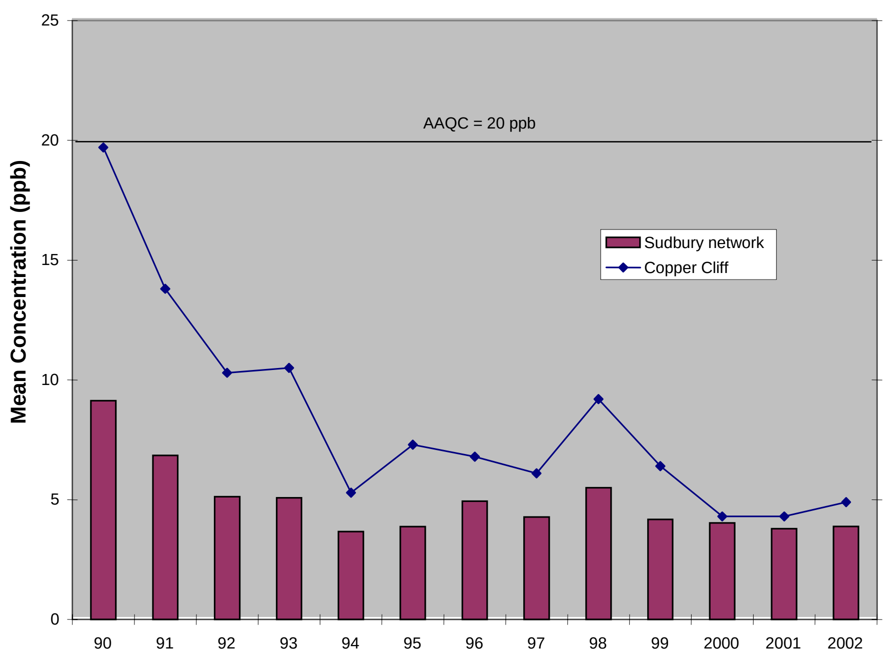

Figure 7: Mean SO_2 concentrations in the Sudbury network and in Copper Cliff

The improvements in air quality significantly reduced the frequency of 'potentially injurious fumigations' (PIFs) to vegetation. PIFs are defined in the 2004 Sudbury air quality report[4] . During the 'pre-1972' era, approximately 35 to over 80 PIFs per growing season were recorded with a network of 10 stations (Dreisinger and McGovern, 1970; McIlveen and Balsillie, 1978). During the 1980s, the occurrence of PIF events had dropped to less than 5 per year with a network of 17 stations (Negusanti and McIlveen, 1990). That trend continued such that by the mid-1990s PIFs had become isolated events. Since 1993, only one PIF event has been recorded (in 1997). The combination of reduced emissions and the implementation of supplementary emission control programs markedly reduced the intensity and duration of SO_2 fumigations. These vastly improved conditions have enabled the successful re-greening of the Sudbury landscape with some of the most SO_2 sensitive tree species such as white pine.

Figure 8 shows the trend in the frequency of hourly concentrations greater than the 1-hour and 24-hour provincial criterion for the 2002 network. From 1990 to 1993, the network recorded an annual average of 246 hours above the 1-hour criterion. The combination of reduced emissions required by the provincial

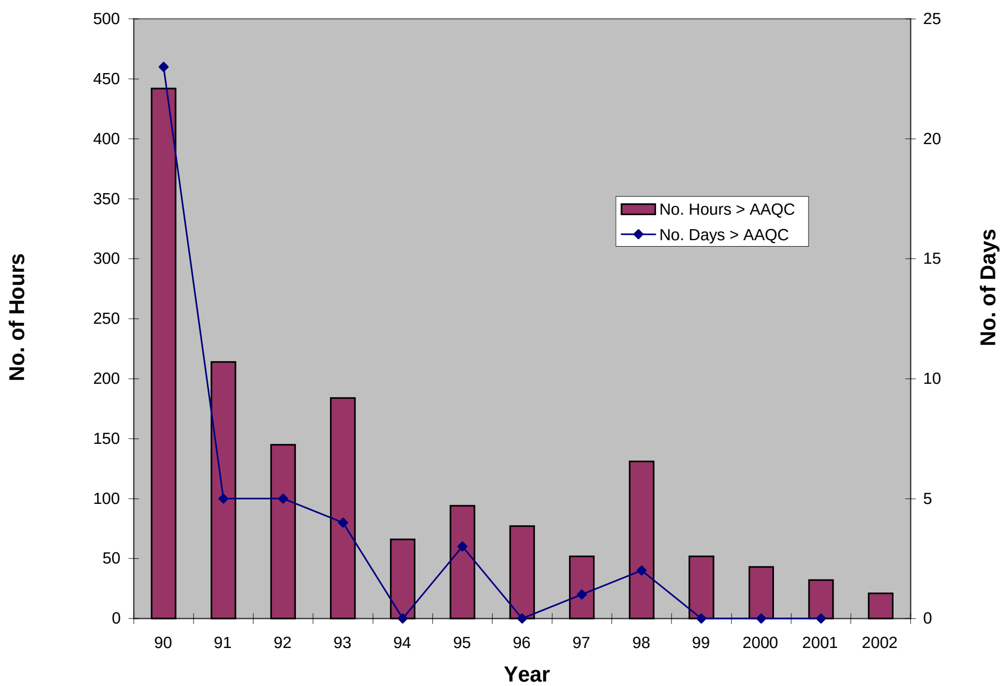

Figure 8: Frequency of Exceedance of the SO_2 AAQCs in Sudbury

acid rain regulations imposed in 1994 and improved operating procedures in the smelters to reduce fugitive emissions resulted in a significant reduction in the frequency of these events. In fact, since 1999 the network recorded an annual average of 37 hours above the 1-hour criterion, a drop of 85% from the period 1990-1993. These improvements are also reflected in the reduced occurrence of average concentrations above the 24-hour criterion, the majority being recorded at the Copper Cliff site. Since 1998, this criterion has been met at all monitoring sites.

Comparisons with Other Cities in Ontario (1990 – 2002)

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[4] Air Quality Trends City of Greater Sudbury, Ontario 1953 – 2002, June 2004.

The composite annual mean SO_2 concentrations for the period 1990 to 2002 are shown in Figure 9 or the following cities: Windsor, Hamilton, Toronto, Ottawa, Sault Ste. Marie, Thunder Bay and Sudbury. For each city, the data was taken from an AQI station preferably located in a downtown area; the Science North AQI site was selected for Sudbury. The highest 13-year means (over 6 ppb) were recorded in Windsor and Hamilton, while Thunder Bay recorded the lowest (0.4 ppb). Sudbury recorded a composite mean of 4.2 ppb and ranked 4th best out of the 7 cities compared, behind Thunder Bay, Sault Ste. Marie and Ottawa.

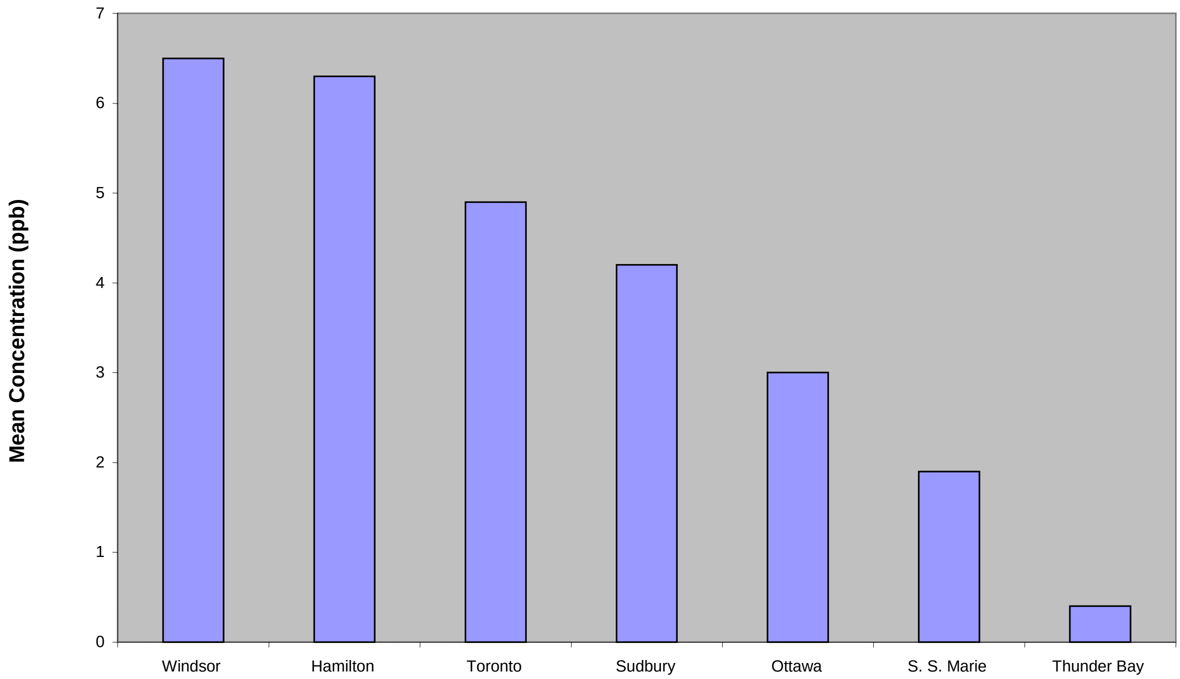

Figure 9: Mean SO_2 Concentrations in selected Ontario cities (1990-2002)

However, a comparison of the annual frequency of occurrence of the 1-hour AAQC (250 ppb) revealed that for the cities selected, Sudbury was the only city that recorded exceedances of the AAQC during this 13-year period.

Air Quality Index (AQI) and SO_2

A description of the AQI system is provided in the 2004 Sudbury air quality report[5]. An AQI station was established in the City of Greater Sudbury at the Science North site in the fall of 1988.

From 1989 to 2001, the AQI described the air quality in the City of Greater Sudbury as being very good (AQI from 0 to 15) to good (AQI from 16 to 31) 94.3% of the time. It also indicated that the air quality was never in the very poor range (AQI > 99). The air quality was determined to be moderate to poor (AQI from 32 to 99) for 5.4% of the time, principally due to elevated ground-level ozone, and to a much lesser extent due to SO_2, and SP (soiling index), as shown in the Table 2. The air quality was determined to be poor (AQI from 50 to 99) for 292 hours (0.3% of the time), again principally due to ground-level ozone (85%) and sulphur dioxide (15%).

[5] Air Quality Trends City of Greater Sudbury, Ontario 1953 – 2002, June 2004.

Table 2: AQI contaminants responsible for moderate to poor air quality in Sudbury from 1989 to 2001

AQI Contaminant	Parameter Responsible For Moderate to Poor Air Quality	Parameter Responsible For Poor Air Quality
O_3	97.5%	85%
SO_2	1.6%	15%

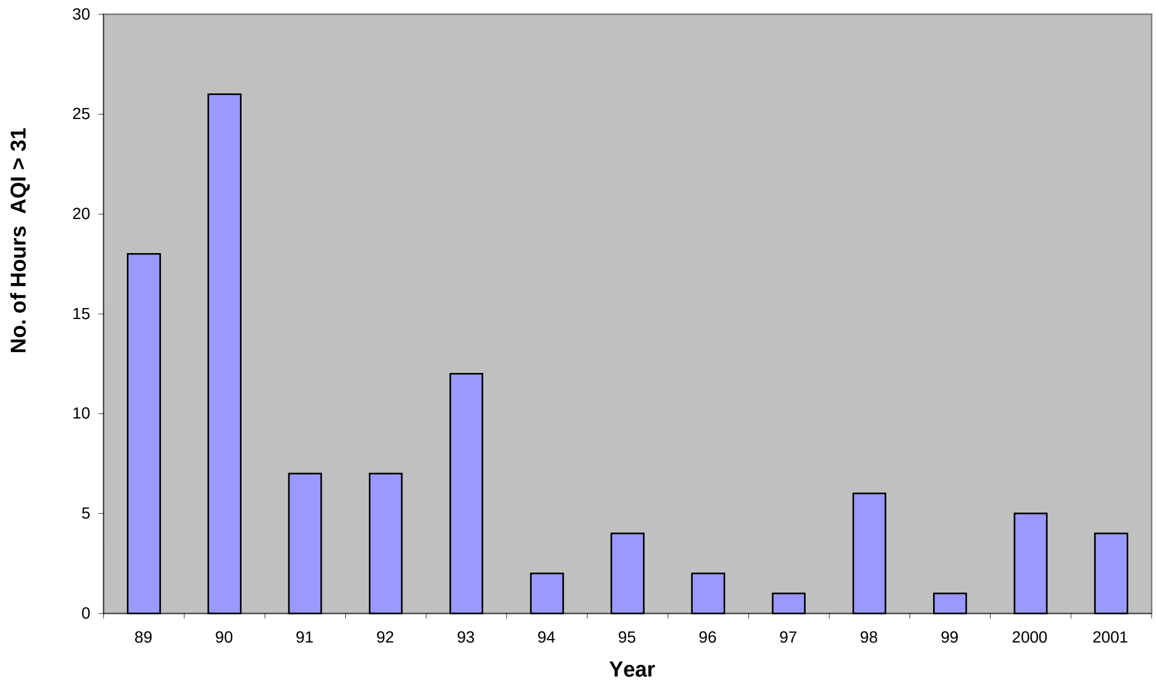

Figure 10: Number of Hours AQI > 31 in Sudbury Due to SO2

The influence of SO_2 on the frequency of hours with AQI >31, corresponding to an hourly SO_2 concentration of 0.25 ppm (250 ppb) or greater, is shown above in Figure 10. Prior to 1994, this pollutant was responsible for an average of 14 hours/year of recorded AQI values > 31. Since 1994, this average has decreased to 3 hours/year.

Comparison with Other Cities in Ontario

As in Sudbury, in any given year the air quality in major urban centres of Ontario has historically been very good to good the majority of the time, i.e. in the low to mid-90% range. Hence moderate to poor air quality has typically occurred less than about 6% to 7% of the time. The composite mean frequency of occurrence of moderate to poor air quality in selected cities of Ontario, expressed as a percentage of the number of hours monitored at each location, is shown in Figure 11. Windsor recorded the highest frequency (6%), followed by Sudbury (5.4%) and Hamilton (5.2%).

The lower grouping was comprised of Toronto, Sault Ste Marie and Ottawa (all at about 3%), and Thunder Bay, the lowest at 1.2%. During the period 1989 to 2001, the air quality in the selected cities was never in the poor category.

At all locations, ground-level ozone was the pollutant largely responsible (upper 90% range) for AQI values >31. Suspended particulate matter, expressed as soiling index, contributed to AQI values >31 mostly in Hamilton, Sault Ste Marie, and Windsor, whereas the contribution from TRS was greatest in Hamilton, Sault Ste Marie and Thunder Bay. During this 13-year period, Sudbury was the only city to record moderate to poor air quality due to SO_2

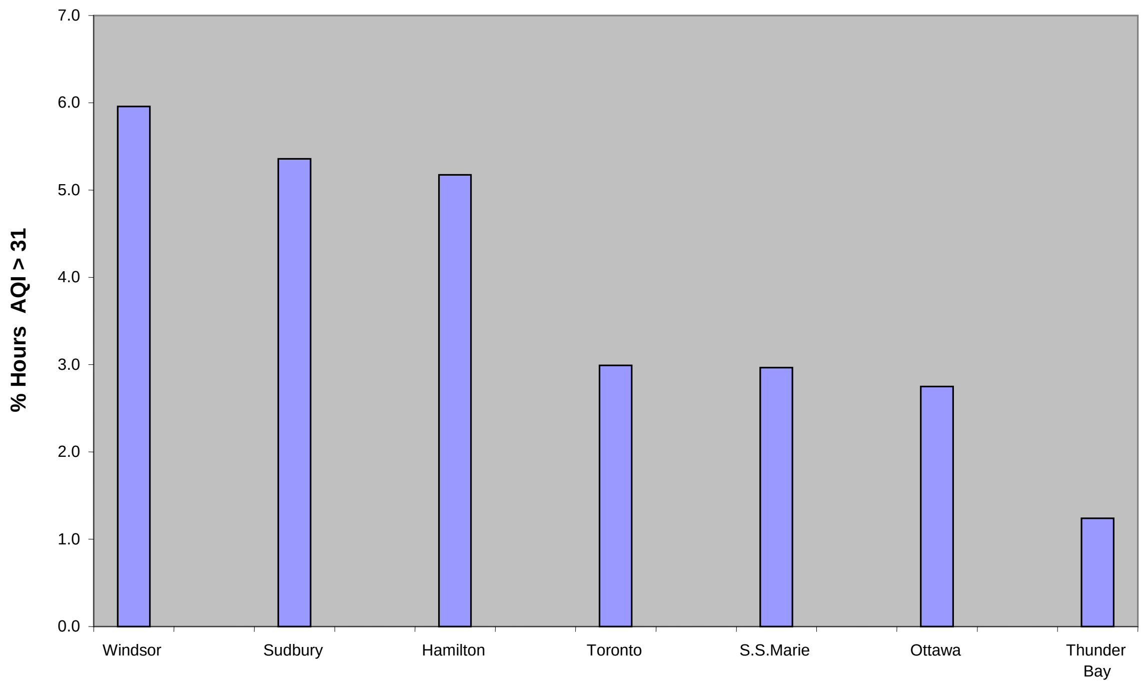

Figure 11: Percentage no. of hours with AQI > 31 in selected Ontario cities (1989-2001)

Concluding Remarks

Almost fifty years after the establishment of the first network of sulphur dioxide monitoring stations, there has been not only significant but continued improvement in air quality in the Sudbury area as determined from sulphur dioxide measurements.

The combination of greatly reduced smelter emissions, improved dispersion and supplementary emission controls has been responsible for significant decreases in the annual concentration, in the intensity and duration of fumigation events and in the frequency of exceedance of the ambient air quality criteria for sulphur dioxide. The dramatic improvements have enabled the Sudbury area to be transformed from its infamous barren landscape to its ‘re-greened’ environment where vegetation injury is an exception rather than the rule. In spite of these achievements, it should be noted that the occurrence of short-term fumigation events typically from April to September, although greatly reduced in number and intensity, remains an issue. Further improvements in this area are expected over time as government and industry work together to achieve further reductions.

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